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SCIENTIFIC INVESTIGATIONS

Analysis of risk factors for air leakage in auto-titrating positive airway pressure users: a single-center study

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Study Objectives: Because air leakage from masks is known as a common cause of low adherence to continuous positive airway pressure therapy, we analyzed the risk factors for air leakage related to parameters associated with auto-titrating positive airway pressure, polysomnography, InBody Test, and rhinomanometry.
Methods: Usage data and medical records of 120 auto-titrating positive airway pressure users were reviewed retrospectively. All patients used a nasal or pillow mask and were carefully monitored at scheduled follow-ups.
Results: Use of a pillow mask, sex (male), age, and abdominal fat percentage were significantly associated with high average air leakage. The higher the auto-titrating positive airway pressure average and mean pressure, the more likely patients exhibited high rates of air leakage. The percentage of patients with high average air leakage increased over time (up to 6 months of follow-up).
Conclusions: Older male patients using a pillow mask and those with a high abdominal fat percentage and high auto-titrating positive airway pressure may require close follow-up and continuous monitoring for air leakage. Because air leakage from a mask can change over time, mask-sealing capacity should be reassessed and masks should be changed regularly.
Keywords: OSA, APAP, mask type, air leakage
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BRIEF SUMMARY
Current Knowledge/Study Rationale: Many previous studies have attempted to determine the effect of masks or device type on air leakage and adherence. However, the effects of nasal cavity resistance and body composition on air leakage and other causes air leakage have yet to be fully evaluated.
Study Impact: This study showed that age, sex, mask type, obesity, and auto-titrating positive airway pressure may be related to high average air leakage and that average air leakage from a mask may change over time. Continuous monitoring for air leakage and scheduled changes of mask may be important in patients with risk factors.

INTRODUCTION

The prevalence of sleep apnea syndrome, as defined by an apnea-hypopnea index (AHI) score of 5 events/h or higher and daytime somnolence, is estimated at 4% in men and 2% in women and the prevalence of sleep-disordered breathing occurs in 4% of men and 9% of women, by the definition of AHI of 5 events/h or higher.[1] Obstructive sleep apnea (OSA) is also associated with an increased risk of cardiovascular or cerebrovascular disease and reduced quality of life.[2–4] In addition, high morbidity and mortality rates are associated with OSA.[5]

Since the positive airway pressure (PAP) device was introduced by Sullivan in Australia in 1981, continuous positive airway pressure (CPAP) has been widely used for OSA treatment and is recommended as first-line treatments for moderate to severe OSA.[6]

To date, 3 main devices have been developed for OSA: CPAP, bilevel PAP, and auto-titrating PAP (APAP). Pressure-relief modes such as expiratory pressure relief by ResMed and C-flex by Respironics have been developed to temporarily reduce pressure during exhalation and ease patient discomfort. APAP devices were developed to reduce mean CPAP pressure and pressure-related side effects of CPAP devices, which are controlled by an auto-adjusting pressure algorithm. Either a CPAP or APAP device is now recommended for ongoing treatment of OSA in adults.[7,8]

There was a meaningful study that compared 3 different methods of CPAP delivery: (1) autotitration, (2) autotitration for 1 week followed by fixed pressure (95th centile), and (3) fixed pressure by algorithm based on neck size and dip rate. Although average pressures were reportedly lowest in a 6-month autotitration group, no significant difference was reported to clinical outcomes among those 3 groups.[9]

Low adherence to PAP treatment is a challenge for many patients with OSA patients. Kohler et al[10] reported that the severity of sleep-disordered breathing, age, and CPAP device pressure were associated with long-term adherence to CPAP.

Van Ryswyk et al[11] reported that approximately one-third of patients using CPAP complain of nasal symptoms and dry mouth and that mask-related problems such as fitting and leakage are reported in 12% of cases at 3 months and 7% of cases at 24 months. Among the side effects of CPAP, the most frequently reported were unintentional air leakage and its related symptoms.[12]

To date, a large number of trials have been conducted to make patients comfortable during PAP therapy and to increase adherence to PAP therapy. Various mask types, primarily nasal pillow, nasal, and full face, may be associated with unintentional air leakage, patient discomfort, and variable adherence. Previous studies have demonstrated that nasal pillows were effective alternative interfaces that achieved adherence rates equal to those of nasal masks.[13,14] However, oronasal masks were reportedly associated with a higher risk of CPAP nonadherence compared with nasal or nasal pillow masks.[15]

With regard to the relationship between the type of CPAP device and air leakage, Lebret et al[16] showed that the type of CPAP device did not influence the amount of air leakage.

Given these findings, air leakage can be considered one of the most troublesome side effects of PAP therapy and a possible cause of low adherence, which is one of the weakest aspects of PAP therapy.

A number of studies have examined the factors that influence air leakage, but none have determined whether the effects on air leakage are temporary or continuous. In addition, the effects of nasal cavity resistance and body composition on air leakage have not been demonstrated in detail.

The objectives of this study were to identify risk factors for air leakage in APAP users with respect to patient demographics, polysomnography (PSG), rhinomanometry, and body composition data and to determine whether such effects change over time.

METHODS

Data collection

From January 2017 to May 2020, APAP usage data and medical records from 122 patients with mild to severe OSA were reviewed retrospectively. All patients completed the Berlin questionnaire and were evaluated using the Epworth Sleepiness Scale, an otolaryngology examination, InBody Test (InBody 770, InBody Co., Ltd., Seoul, Korea), rhinomanometry, and full-night in-lab PSG. Patients with severe respiratory disease, severe cardiovascular disease, and cognitive impairment were excluded, and patients who used APAP manufactured by companies other than Respironics before January 2017 were also excluded to maintain data uniformity. Of the 122 patients included in this study, 1 patient using a full-face mask and 1 patient with follow-up loss were excluded. Finally, data of 120 patients were included in the analysis. Follow-ups were scheduled at first (2 weeks after using APAP), second (1 month from first follow-up, from 2 weeks to 1.5 months after using APAP), third (3 months from second follow-up, from 1.5 to 4.5 months after using APAP), and fourth (3 months from third follow-up, from 4.5 to 10.5 months after using APAP). The number of patients at each follow-up were 120, 119, 100, and 60 respectively (**Figure 1**).

All patients were provided with an APAP device and mask by the same manufacturer (Philips Respironics, Murrysville, PA)—either a nasal mask (DreamWear or Wisp Nasal mask; Philips Respironics) or a pillow mask (DreamWear Gel Nasal Pillow mask; Philips Respironics). When a doctor prescribed an APAP device, the patient was given masks and cushions of different sizes and allowed to choose a mask that fit best at hospital. If a patient complained of mask leakage or felt uncomfortable, a different size of mask or cushion with same interface initially supplied could be used within the first 2 weeks (at the first follow-up).

Although many mask manufacturers suggest replacing mask cushions once or twice a month, Korean national health care insurance only covers the costs of mask replacement once a year. In this study no mask cushions were replaced over the course of the 6 months.

Although APAP pressures ranged from 4 cm H_2O to 16 cm H_2O, low-span APAP settings with the window of pressure variation less than 5 cm H_2O were used and the upper pressure of low-span APAP settings was less than 12 cm H_2O in all but 6 patients. A previous paper used low-span APAP setting with pressure range from 8 cm H_2O to 12 cm H_2O, which meant the window of low-span APAP pressure was 4 cm H_2O.[17]

All patients used heated humidification and a pressure-relief mode (A-flex 2 or 3), but 6 patients did not temporarily use heated humidification. When a patient visited the clinic, detailed data for the 7 days prior to the follow-up day were extracted from the APAP device with Philips EncorePro2 (version 2.23.03) software as follows: average device pressure under 90% of time (90% ADP; cm H_2O), mean pressure (cm H_2O), large air leakage (%time), AHI (events/h), rate of device use (greater than 70% or not, greater than 50% or not), average usage (all days), average usage (days used). H-average air leakage in this study was defined as the highest value of daily average air leakages in liters per minute (LPM), which was checked after reviewing daily average air leakages in between follow-ups.

The protocol for this study was approved by the Institutional Review Committee, St. Vincent Hospital, The Catholic University, Suwon, Republic of Korea (VC20RISI0194).

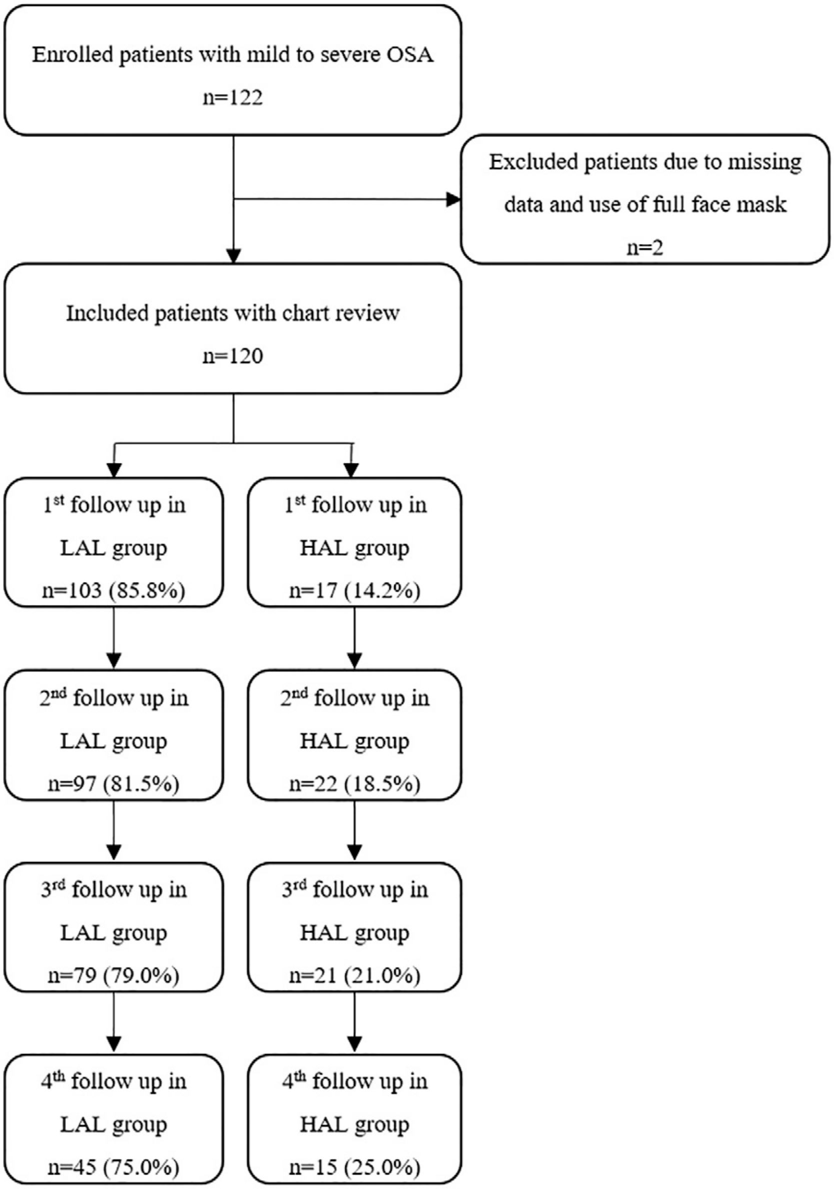
Rhinomanometry for nasal air flow and resistance

Our clinic used active anterior rhinomanometry, which is the most commonly used rhinomanometric tool because of its superior performance in measuring nasal cavity resistance and patency compared with acoustic rhinomanometry. A technician skilled in the use of a rhinorrheograph MRP-3100 (Nihon Kohden Co., Tokyo, Japan) performed all measurements. All patients were examined in a temperature-controlled and humidity-controlled room. One nasal cavity was blocked, and the opposite side was opened. The technician measured the low rate of the open nasal cavity, with a nasal adapter positioned in front of one nostril. Because resistance in the nasal cavity can change due to the nasal cycle, transnasal pressure was changed from 75 to 150 Pa to measure basal resistance. Nasal cavity resistance was measured by dividing transnasal pressure by natural airflow (V) at each nostril. The value of transnasal resistance (Pa/cm^3/second) was calculated using Standardization Committee on Objective Assessment of the Nasal Airway recommendations.

Polysomnography

Full-night in-laboratory PSG was performed at the sleep center of St. Vincent Hospital, Suwon, Gyeonggi Province, Republic of

Figure 1—Study flowchart: changes of enrolled patients with low and high h-average air leakage over time.



HAL = high h-average air leakage, LAL = low h-average air leakage, OSA = obstructive sleep apnea.

Korea. During PSG tests, sensors used to record various biological signals were as follows: 6 electroencephalography (F3, F4, C3, C4, O1, O2); 2 electrooculography; 1 electrocardiogram lead; and 3 electromyography leads at the submentum, anterior tibial muscle, left and right sides; and a body-position sensor. A nasal pressure transducer, oral thermistor, thoracic and abdominal respiratory plethysmography belts, a pulse oximeter, and a snoring sensor were used to monitor respiratory events during sleep.

The full-night in-laboratory PSG data were recorded Embla N7000/S7000 hardware (Embla Systems, Inc., Broomfield, CO). All PSG data were manually scored by 2 sleep technicians and reviewed by a sleep specialist according to criteria of the American Academy of Sleep Medicine Scoring Manual version 2.4.[18]

Statistical analysis

Data are expressed as means ± standard deviation or standard error, including the interquartile range for continuous variables and the number or percentage for categorical variables. Baseline continuous or categorical variables were analyzed by independent *t*-tests or Wilcoxon ranking sum tests based on normality, chi-square tests, or Fisher's exact tests. For longitudinal data, a generalized linear mixed model was used to estimate the association between maximal air leakage and independent variables. The generalized linear mixed model protocol uses a fixed effect for the independent variable and a random effect over time (2 weeks, 1 month, 3 months, or 6 months) and a binomial distribution with a logit link function model. We used a variance component structure for random effects. In addition, we analyzed the association of h-average air leakage with 90% ADP, mean pressure, device-estimated AHI, large leaks (%time) and average usage time (average usage [all days], average usage [days used]). Multivariate analysis was not performed to prevent overfitting according to the rule of experiencing at least 10 events per variable. Results were not corrected for multiple tests as each of the independent variables was considered to be of interest. A P value < 0.05 was considered statistically significant. All data analyses were performed using SAS 9.4 (SAS Institute, Inc., Cary, NC).

RESULTS

Data of 120 patients were reviewed retrospectively and the demographic and clinical characteristics of all patients are provided in **Table 1**.

Overall changes in patients with low and high average air leakage during APAP use

In this study, the threshold for division into low h-average air leakage (LAL) and high h-average air leakage (HAL) subgroups was defined as 40 LPM. Philips Respironics devices provide total leakage data (unintentional leakage plus intentional air leakage) and tolerate leakage of up to twice an intentional leak. Intentional air leakage varies by mask type and PAP pressure. In this study, given that the upper pressure of low-span APAP treatment ranged from 9 to 16 cmH_2O, the calculated intentional air leakage ranged from approximately 26 to 35 LPM for both mask types (DreamWear/Wisp nasal and DreamWear pillow mask). The definition of a large leak threshold is total leakage of more than twice the intentional leak at each pressure for 1.5 min, which ranges from 52 to 70 LPM in this study. A large leak (%time) was defined as the percentage of time spent with the large leak. Philips Respironics machines tolerate up to 2 times the intentional leaks. If the patient has a perfect mask seal, the device will notice a total leak value that is equal to the intentional leak from the exhalation port. Any leaks between the cushion and the patient's face will be detected by device and considered to be unintentional leaks.[19,20]

Because the mean of 90% ADP of all patients was 9.4 cm H_2O, we divided patients into 2 subgroups, with a median value between intentional and large-leak thresholds of 40 LPM at this pressure. The proportion of patients with a HAL greater than 40 LPM was between 14.2 and 25% during 4 follow-ups. This proportion increased continuously when follow-up assessments were repeated (**Figure 1**).

Estimated risk factors on HAL

The characteristics of patients with LAL and HAL were compared at each follow-up (**Table 2**).

Although previous reports have demonstrated that nasal pillows are effective alternative interfaces and achieve adherence rates comparable to a nasal mask, data of 120 patients were further analyzed after division into 2 subgroups according to mask type to identify the relationship between mask type and air leakage not from the point of view of adherence.[13,14]

On the first APAP follow-up, significant differences between the LAL and HAL groups were found in sex, nasal flow of the dominant side less than 300 Pa, tonsil size, palatal position, neck circumference, waist/hip ratio, supine AHI, and minimal saturation. However, because the period of the first follow-up was only 2 weeks after APAP use and was thought to be the initial adaptation period to the APAP and mask, these data were considered less important than the second, third, and fourth follow-up points and were not used in further evaluation.

On the second and third APAP follow-ups, age, body mass index (BMI), neck/waist/hip circumference, neck-hip ratio, and minimal saturation were significantly different between LAL and HAL groups.

On the fourth APAP follow-up (more than 6 months of APAP use), BMI, body fat, visceral fat area (cm^2), abdominal fat percentage, neck circumference, and some PSG data (AHI, supine AHI, minimal saturation) were significantly different between LAL and HAL groups. From the second to the fourth APAP follow-up (most of the APAP use period), BMI, neck circumference, and minimal saturation were significantly different between LAL and HAL groups (**Table 2**).

Nasal flow and resistance of the dominant side before nasal cavity constriction, tonsil size, and palatal position were significantly different between LAL and HAL groups only at the first or second follow-ups (**Table 2**), but the odds ratios (ORs) of nasal flow and resistance parameters were approximately 1.0 or not significant (**Table 3**).

A few PSG parameters such as supine AHI and minimal saturation were significantly different between LAL and HAL groups (**Table 2**) but the estimated ORs of all PSG parameters for HAL were small (approximately 1.00) (**Table 3**).

Although tonsil size and palatal position were significantly different only at the first follow-up, their ORs were 0.62 (confidence interval [CI] 0.40–0.95) and 0.55 (CI 0.39–0.77), respectively, which were contrary to our expectation (**Table 2** and **Table 3**).

As shown in **Table 3**, pillow mask (OR 1.96, 95% CI 1.05–3.66), male sex, and age (more than 65 years, OR 2.31, 95% CI 1.12–4.76) were closely related to HAL with large ORs. In particular, abdominal fat percentage (OR 2.88) was more closely associated with HAL than with BMI (OR 1.18), body fat (OR 1.06), visceral fat area (OR 1.01), hip circumference (OR 1.06), and neck-hip ratio (OR 1.15).

For the average usage (all days) and average usage (days used), there was no significant difference between HAL and LAL groups except for the second follow-up. Only at the second follow-up, the average usage time of the LAL group was significantly longer than that of the HAL group (**Table 2**).

Association of APAP pressure and device-estimated AHI with risk of high average air leakage

In each subgroup, LAL and HAL, 90% ADP, mean pressure, and device-estimate AHI among second, third, and fourth follow-ups showed a decreasing trend (negative beta values) but were not statistically significant (**Table 4**). However, large leaks (%time) significantly increased in LAL but not in HAL groups (**Table 4**).

The average usage (all days) and average usage (days used) significantly decreased in LAL group but average usage for used days significantly increased in HAL group (**Table 4**). In addition,

Table 1—Demographic and clinical characteristics of the 120 enrolled patients.

	All Patients (n = 120)	Patients with LAL (n = 103)	Patients with HAL (n = 17)
Anthropometric data			
Sex (male n, %)	99 (82.5)	82 (79.6)	17 (100.0)
Age (years)	51.9 ± 10.5	52.1 ± 10.3	51.0 ± 11.3
Nasal stuffiness (yes, n %)	38 (31.7)	34 (33.0)	4 (23.5)
Mouth breathing (yes, n %)	64 (53.3)	56 (54.4)	8 (47.1)
Physical examination			
Tonsil size (1–4)	1.8 ± 0.8	1.87 ± 0.08	1.53 ± 0.17
Palatal position (1–3)	2.5 ± 0.7	2.52 ± 0.07	2.06 ± 0.18
Muller maneuver (0–3)	0.9 ± 0.8	0.91 ± 0.08	0.76 ± 0.14
Comorbidities			
Treated for hypertension (%)	35.0	32.7	50.0
Treated for diabetes (%)	12.5	12.5	12.5
Treated for dyslipidemia (%)	8.3	5.8	25.0
Treated for COPD or asthma (%)	1.7	1.9	0.0
Treated for cardiovascular disease (%)	5.0	4.8	6.3
Treated for cerebellar vascular disease (%)	3.3	2.9	6.3
Treated for other disease (Parkinson, thyroid) (%)	9.2	7.7	6.3
Body composition			
BMI (kg/m^2)	28.1 ± 3.9	27.88 ± 0.38	29.35 ± 0.97
Body fat (kg)	24.6 ± 7.7	24.32 ± 0.76	26.43 ± 2.22
Body fat percentage (%)	29.8 ± 6.5	29.99 ± 0.66	28.78 ± 1.73
Visceral fat area (cm^2)	109.7 ± 37.2	108.39 ± 3.69	117.57 ± 10.82
Abdominal fat percentage (%)	0.9 ± 0.1	0.92 ± 0.01	0.95 ± 0.02
Neck circumference (cm)	39.7 ± 4.0	39.41 ± 0.42	41.35 ± 0.78
Waist circumference (cm)	95.1 ± 13.0	95.22 ± 1.07	94.22 ± 5.90
Hip circumference (cm)	103.6 ± 7.8	103.47 ± 0.81	104.41 ± 1.77
Neck-hip ratio (NHR)	0.4 ± 0.0	0.38 ± 0.00	0.40 ± 0.01
Waist-hip ratio (WHR)	0.9 ± 0.1	0.92 ± 0.01	0.90 ± 0.05
Severity of OSA at diagnosis			
AHI (events/h)	50.2 ± 23.5	48.46 ± 2.25	60.64 ± 6.19
Obstructive type	22.1 ± 22.2	20.24 ± 2.02	33.55 ± 6.99
Hypopnea type	23.8 ± 13.8	24.36 ± 1.36	20.24 ± 3.29
REM AHI	45.7 ± 23.8	44.51 ± 2.31	53.07 ± 6.16
Supine AHI	53.8 ± 40.2	52.49 ± 4.21	61.69 ± 5.03
Minimal saturation (%)	74.2 ± 16.0	75.25 ± 1.60	67.88 ± 3.21
Periodic limb movements in sleep index	9.7 ± 20.1	10.65 ± 2.09	4.02 ± 2.62
Epworth Sleepiness Scale (0–24)	10.6 ± 5.2	10.45 ± 0.52	11.47 ± 1.39
Berlin questionnaire (0–22)	7.7 ± 3.5	7.68 ± 0.38	7.59 ± 0.39
Rhinomanometry			
Total resistance less than 75 Pa (before constriction)	0.14 ± 0.08	0.14 ± 0.01	0.12 ± 0.01
Total resistance less than 150 Pa (before constriction)	0.20 ± 0.12	0.21 ± 0.01	0.16 ± 0.02
Nasal flow of dominant side less than 75 Pa (before constriction)	284.8 ± 182.5	282.33 ± 18.52	299.87 ± 58.31
Nasal flow of dominant side less than 150 Pa (before constriction)	381.0 ± 212.6	371.24 ± 22.03	439.20 ± 59.91
Nasal flow of dominant side less than 300 Pa (before constriction)	360.2 ± 290.4	330.54 ± 29.80	538.40 ± 72.43

(continued on following page)

Table 1—Demographic and clinical characteristics of the 120 enrolled patients. (*Continued*)

	All Patients (n = 120)	Patients with LAL (n = 103)	Patients with HAL (n = 17)
Resistance of dominant side less than 75 Pa (before constriction)	0.42 ± 0.66	0.45 ± 0.07	0.29 ± 0.05
Resistance of dominant side less than 150 Pa (before constriction)	0.50 ± 0.50	0.53 ± 0.06	0.36 ± 0.06
Resistance of dominant side less than 300 Pa (before constriction)	0.63 ± 0.81	0.65 ± 0.09	0.54 ± 0.12
Nasal flow of dominant side less than 75 Pa (after constriction)	352.6 ± 204.4	341.99 ± 21.86	414.57 ± 63.54
Nasal flow of dominant side less than 150 Pa (after constriction)	431.9 ± 242.8	417.85 ± 25.91	514.00 ± 75.28
Nasal flow of dominant side less than 300 Pa (after constriction)	374.3 ± 342.2	370.93 ± 35.82	393.71 ± 119.38
Resistance of dominant side less than 75 Pa (after constriction)	0.28 ± 0.28	0.29 ± 0.03	0.22 ± 0.02
Resistance of dominant side less than 150 Pa (after constriction)	0.36 ± 0.32	0.37 ± 0.04	0.29 ± 0.04
Resistance of dominant side less than 300 Pa (after constriction)	0.39 ± 0.42	0.42 ± 0.05	0.21 ± 0.07

Data are reported as median values or percentages. AHI = apnea-hypopnea index, BMI = body mass index, COPD = chronic obstruction pulmonary disease, HAL = high h-average air leakage, LAL = low h-average air leakage, REM = rapid eye movement.

our results showed that AHI (OR 1.38, 95% CI 1.17–1.62, $P < .001$), 90% ADP (OR 1.93, 95% CI 1.52–2.45, $P < 0.001$), and mean pressure (OR 1.89, 95% CI 1.52–2.35, $P < 0.001$), and large leaks (OR 2.3, CI 1.66–3.20, $P < 0.001$) were risk factors for HAL (**Table 5**).

DISCUSSION

CPAP is recommended as a first-line treatment for moderate to severe OSA and low adherence remains a major problem in long-term PAP treatments.[7,8]

CPAP adherence is influenced by a variety of factors, such as knowledge of OSA/perception of CPAP treatment, mask interfaces, drying of upper airway mucosa, claustrophobia, early follow-up within the first week after CPAP treatment.[21]

The appropriate selection of mask interfaces, typically a nasal, nasal pillow, and oronasal mask, is thought to be the first step in effective CPAP adherence. Several studies of the relationship between mask type and CPAP adherence have been conducted. Borel et al[15] used multivariate analysis to show that oronasal masks were associated with a higher risk of CPAP nonadherence compared with nasal or nasal pillow masks.

However, it was also reported that CPAP adherence did not differ between the 3 different mask interfaces (ie, nasal mask with or without chin strap and an oronasal mask) but fewer air leaks and mask-fitting problems were associated with nasal mask compared with nasal mask chin-straps and oronasal masks.[22]

Previous studies, including the 2 cited above, showed that nasal masks achieve superior adherence compared with pillow-type and oronasal-type masks.[23–26]

Air leakage and its side effects are prevalent in long-term CPAP-treated patients and Valentin et al reported that greater air leakage was associated with poor adherence to APAP therapy.[27,28] Therefore, among a variety of factors affecting CPAP adherence, considerable attention has been paid to air leakage and mask-related factors.

Although Lebret et al[12] reported that nasal obstruction, higher BMI, older age, and male sex are related to air leakage, our results suggest additional risk factors, such as pillow mask, male sex, and older age, are related to air leakage.

The pillow mask is well-tolerated, an effective interface, and smaller than the nasal-type and oronasal-type masks, which explains why it is frequently chosen by patients. However, our results showed that use of pillow masks may be a risk factor for air leakage and a negative factor for PAP adherence.

Aging is a well-known risk factor that can increase upper airway collapse due to low neuromuscular function, a relationship that was confirmed by our results.[29]

The unintentional leaks during APAP treatment were reported to be related to mouth opening, CPAP level, sleep position, and rapid eye movement sleep, and oronasal masks can reduce the risk of unintentional air leakage in the case of mouth breathing and rapid eye movement sleep.[30]

Our results showed that higher APAP pressure (90th percentile, mean pressure) may be related to HAL. Patients with a high 90% ADP or mean pressure should therefore be closely monitored for air leakage regardless of initial air leakage values.

A study with patients with extreme obesity (a median BMI of at least 43 kg/m^2) reported that BMI, neck circumference, and waist circumference are not predictive of APAP pressure.[31]

Table 2—Characteristics of patients with high and low h-average air leakage at 4 follow-ups.

	h-Average Air Leakage (LPM)											
	First APAP Follow-up (2 Weeks)			Second APAP Follow-up (1 Month)			Third APAP Follow-up (3 Months)			Fourth APAP Follow-up (6 Months)		
	< 40 (n = 103)	≥ 40 (n = 17)	*P*	< 40 (n = 97)	≥ 40 (n = 22)	*P*	< 40 (n = 79)	≥ 40 (n = 21)	*P*	<40 (n = 45)	≥40 (n = 15)	*P*
Mask type			.699			.173			.097			>.999
Nasal (n (%))	90 (87.4)	14 (82.4)		86 (88.7)	17 (77.3)		69 (87.3)	15 (71.4)		34 (75.6)	11 (73.3)	
Pillow (n (%))	13 (12.6)	3 (17.6)		11 (11.3)	5 (22.7)		10 (12.7)	6 (28.6)		11 (24.4)	4 (26.7)	
Sex (male, n (%))	82 (79.6)	17 (100.0)	.041	77 (79.4)	21 (95.5)	.118	61 (77.2)	20 (95.2)	.068	37 (82.2)	13 (86.7)	>.999
Age (years)			>.999			.030			.032			>.999
<65 (n (%))	93 (90.3)	16 (94.1)		91 (93.8)	17 (77.3)		74 (93.7)	16 (76.2)		39 (86.7)	13 (86.7)	
≥65 (n (%))	10 (9.7)	1 (5.9)		6 (6.2)	5 (22.7)		5 (6.3)	5 (23.8)		6 (13.3)	2 (13.3)	
Nasal stuffiness (yes, n (%))	34 (33.0)	4 (23.5)	.436	28 (28.9)	10 (45.5)	.132	25 (31.6)	7 (33.3)	.883	11 (24.4)	4 (26.7)	>.999
Mouth breathing (yes, n (%))	56 (54.4)	8 (47.1)	.576	49 (50.5)	15 (68.2)	.134	41 (51.9)	13 (61.9)	.414	24 (53.3)	12 (80.0)	.068
Rhinomanometry												
Total resistance less than 75 Pa (before constriction)	0.14 ± 0.01	0.12 ± 0.01	.591	0.14 ± 0.01	0.12 ± 0.01	.909	0.14 ± 0.01	0.14 ± 0.02	.966	0.13 ± 0.01	0.13 ± 0.02	.879
Total resistance less than 150 Pa (before constriction)	0.21 ± 0.01	0.16 ± 0.02	.149	0.21 ± 0.01	0.16 ± 0.02	.210	0.21 ± 0.02	0.19 ± 0.02	.861	0.19 ± 0.02	0.19 ± 0.02	.571
Nasal flow of dominant side less than 75 Pa (before constriction)	282.33 ± 18.52	299.87 ± 58.31	.993	279.47 ± 19.10	299.65 ± 50.13	.765	263.91 ± 22.19	340.56 ± 49.06	.103	320.05 ± 34.92	290.17 ± 50.75	.939
Nasal flow of dominant side less than 150 Pa (before constriction)	371.24 ± 22.03	439.20 ± 59.91	.220	369.01 ± 21.59	424.24 ± 62.93	.401	337.76 ± 23.81	449.33 ± 54.47	.039	378.30 ± 37.90	452.67 ± 62.79	.232
Nasal flow of dominant side less than 300 Pa (before constriction)	330.54 ± 29.80	538.40 ± 72.43	.011	348.43 ± 29.25	441.88 ± 88.12	.293	330.18 ± 30.12	490.28 ± 80.88	.029	308.53 ± 42.01	454.00 ± 112.06	.218
Resistance of dominant side less than 75 Pa (before constriction)	0.45 ± 0.07	0.29 ± 0.05	.178	0.44 ± 0.08	0.37 ± 0.08	.439	0.49 ± 0.10	0.30 ± 0.06	.049	0.53 ± 0.16	0.34 ± 0.07	.704
Resistance of dominant side less than 150 Pa (before constriction)	0.53 ± 0.06	0.36 ± 0.06	.142	0.50 ± 0.05	0.51 ± 0.12	.367	0.57 ± 0.07	0.40 ± 0.08	.048	0.55 ± 0.11	0.50 ± 0.13	.728
Resistance of dominant side less than 300 Pa (before constriction)	0.65 ± 0.09	0.54 ± 0.12	.778	0.62 ± 0.09	0.72 ± 0.21	.713	0.73 ± 0.11	0.58 ± 0.15	.276	0.74 ± 0.18	0.59 ± 0.21	.575
Nasal flow of dominant side less than 75 Pa (after constriction)	341.99 ± 21.86	414.57 ± 63.54	.329	339.84 ± 22.39	400.27 ± 56.25	.364	317.08 ± 19.63	325.25 ± 37.09	.911	320.23 ± 26.21	297.60 ± 39.28	.652
			.299			.196			.706			.816

(continued on following page)

Table 2—Characteristics of patients with high and low h-average air leakage at 4 follow-ups. (*Continued*)

	h-Average Air Leakage (LPM)											
	First APAP Follow-up (2 Weeks)			Second APAP Follow-up (1 Month)			Third APAP Follow-up (3 Months)			Fourth APAP Follow-up (6 Months)		
	< 40 (n = 103)	≥ 40 (n = 17)	*P*	< 40 (n = 97)	≥ 40 (n = 22)	*P*	< 40 (n = 79)	≥ 40 (n = 21)	*P*	<40 (n = 45)	≥40 (n = 15)	*P*
Nasal flow of dominant side less than 150 Pa (after constriction)	417.85 ± 25.91	514.00 ± 75.28		409.45 ± 25.16	516.27 ± 74.77		393.16 ± 25.80	431.00 ± 52.92		400.17 ± 38.53	444.40 ± 63.04	
Nasal flow of dominant side less than 300 Pa (after constriction)	370.93 ± 35.82	393.71 ± 119.38	.949	375.40 ± 36.20	324.80 ± 106.52	.486	352.19 ± 39.28	469.25 ± 85.56	.236	346.40 ± 54.65	502.40 ± 117.23	.260
Resistance of dominant side less than 75 Pa (after constriction)	0.29 ± 0.03	0.22 ± 0.02	.477	0.29 ± 0.03	0.24 ± 0.03	.507	0.31 ± 0.04	0.27 ± 0.03	.757	0.32 ± 0.07	0.30 ± 0.05	.461
Resistance of dominant side less than 150 Pa (after constriction)	0.37 ± 0.04	0.29 ± 0.04	.467	0.37 ± 0.04	0.32 ± 0.05	.374	0.39 ± 0.05	0.35 ± 0.05	.965	0.40 ± 0.08	0.41 ± 0.06	.420
Resistance of dominant side less than 300 Pa (after constriction)	0.42 ± 0.05	0.21 ± 0.07	.068	0.42 ± 0.05	0.26 ± 0.10	.083	0.42 ± 0.06	0.41 ± 0.08	.848	0.44 ± 0.09	0.49 ± 0.13	.616
Physical examination												
Tonsil size (1–4)	1.87 ± 0.08	1.53 ± 0.17	.037	1.86 ± 0.09	1.68 ± 0.17	.261	1.76 ± 0.07	1.62 ± 0.15	.279	1.64 ± 0.10	1.53 ± 0.19	.482
Palatal position (1–3)	2.52 ± 0.07	2.06 ± 0.18	.011	2.52 ± 0.07	2.18 ± 0.17	.061	2.52 ± 0.08	2.33 ± 0.16	.252	2.47 ± 0.11	2.13 ± 0.22	.149
Muller maneuver (0–3)	0.91 ± 0.08	0.76 ± 0.14	.610	0.90 ± 0.08	0.86 ± 0.19	.732	0.84 ± 0.09	0.90 ± 0.15	.590	0.89 ± 0.10	0.73 ± 0.21	.419
Body composition												
BMI (kg/m^2)	27.88 ± 0.38	29.35 ± 0.97	.075	27.59 ± 0.35	30.33 ± 1.04	.016	27.44 ± 0.38	29.82 ± 0.90	.020	27.55 ± 0.56	31.16 ± 1.02	.005
Body fat (kg)	24.32 ± 0.76	26.43 ± 2.22	.239	23.84 ± 0.75	28.19 ± 2.12	.106	23.77 ± 0.82	26.87 ± 1.75	.175	23.74 ± 1.15	30.14 ± 2.02	.008
Body fat percentage (%)	29.99 ± 0.66	28.78 ± 1.73	.865	29.75 ± 0.71	30.20 ± 1.32	.637	29.83 ± 0.81	30.16 ± 1.21	.581	29.59 ± 1.06	31.82 ± 1.73	.153
Visceral fat area (cm^2)	108.39 ± 3.69	117.57 ± 10.82	.289	106.60 ± 3.72	123.70 ± 9.58	.136	106.93 ± 4.13	118.43 ± 8.08	.223	104.66 ± 5.56	137.91 ± 9.04	.005
Abdominal fat percentage (%)	0.92 ± 0.01	0.95 ± 0.02	.089	0.92 ± 0.01	0.94 ± 0.01	.085	0.91 ± 0.01	0.93 ± 0.01	.169	0.91 ± 0.01	0.96 ± 0.01	.003
Neck circumference (cm)	39.41 ± 0.42	41.35 ± 0.78	.029	39.21 ± 0.43	41.88 ± 0.65	.002	39.11 ± 0.51	41.93 ± 0.59	.001	39.59 ± 0.74	42.14 ± 0.99	.046
Waist circumference (cm)	95.22 ± 1.07	94.22 ± 5.90	.078	94.02 ± 1.27	99.97 ± 3.70	.007	93.71 ± 1.16	96.83 ± 4.88	.002	94.23 ± 1.70	95.46 ± 7.60	.076
Hip circumference (cm)	103.47 ± 0.81	104.41 ± 1.77	.539	102.78 ± 0.79	107.66 ± 1.80	.010	102.74 ± 0.90	106.68 ± 1.31	.015	104.37 ± 1.17	109.46 ± 2.00	.052
Neck-hip ratio (NHR)	0.38 ± 0.00	0.40 ± 0.01	.120	0.38 ± 0.00	0.39 ± 0.01	.294	0.38 ± 0.00	0.39 ± 0.00	.125	0.38 ± 0.01	0.38 ± 0.01	.867

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Table 2—Characteristics of patients with high and low h-average air leakage at 4 follow-ups. (*Continued*)

	h-Average Air Leakage (LPM)											
	First APAP Follow-up (2 Weeks)			Second APAP Follow-up (1 Month)			Third APAP Follow-up (3 Months)			Fourth APAP Follow-up (6 Months)		
	< 40 (n = 103)	≥ 40 (n = 17)	*P*	< 40 (n = 97)	≥ 40 (n = 22)	*P*	< 40 (n = 79)	≥ 40 (n = 21)	*P*	<40 (n = 45)	≥40 (n = 15)	*P*
Waist-hip ratio (WHR)	0.92 ± 0.01	0.90 ± 0.05	.039	0.92 ± 0.01	0.93 ± 0.03	.047	0.91 ± 0.01	0.91 ± 0.04	.023	0.90 ± 0.01	0.87 ± 0.07	.419
Severity of OSA at diagnosis												
AHI (events/h)	48.46 ± 2.25	60.64 ± 6.19	.056	48.82 ± 2.35	55.64 ± 5.39	.266	48.32 ± 2.48	51.15 ± 5.07	.688	44.36 ± 3.10	61.67 ± 5.34	.016
Obstructive type	20.24 ± 2.02	33.55 ± 6.99	.055	20.15 ± 2.16	29.65 ± 5.32	.025	19.65 ± 2.25	24.09 ± 5.13	.283	16.38 ± 2.49	32.66 ± 5.87	.016
Hypopnea type	24.36 ± 1.36	20.24 ± 3.29	.341	24.64 ± 1.40	20.37 ± 2.95	.210	24.21 ± 1.52	22.21 ± 3.38	.446	23.08 ± 1.84	23.19 ± 3.84	.878
REM AHI	44.51 ± 2.31	53.07 ± 6.16	.111	44.10 ± 2.36	53.01 ± 5.53	.121	44.92 ± 2.42	42.46 ± 6.10	.793	43.28 ± 3.05	54.73 ± 5.17	.050
Supine AHI	52.49 ± 4.21	61.69 ± 5.03	.040	53.30 ± 4.45	56.56 ± 4.43	.215	53.08 ± 5.36	57.20 ± 3.80	.039	45.26 ± 3.19	60.25 ± 3.97	.005
Minimal saturation (%)	75.25 ± 1.60	67.88 ± 3.21	.009	74.89 ± 1.74	71.27 ± 2.17	.019	75.87 ± 1.78	71.57 ± 2.55	.045	78.62 ± 1.32	70.00 ± 2.99	.011
Periodic limb movements in sleep index	10.65 ± 2.09	4.02 ± 2.62	.198	9.86 ± 2.13	8.69 ± 3.51	.863	8.97 ± 2.23	10.18 ± 3.31	.361	11.22 ± 3.03	5.27 ± 3.53	.322
Epworth Sleepiness Scale (0–24)	10.45 ± 0.52	11.47 ± 1.39	.653	10.27 ± 0.55	12.10 ± 1.05	.124	9.89 ± 0.59	11.95 ± 1.12	.115	10.44 ± 0.90	10.79 ± 1.46	.860
Berlin questionnaire (0–22)	7.68 ± 0.38	7.59 ± 0.39	.395	7.73 ± 0.39	7.57 ± 0.43	.425	7.81 ± 0.43	7.62 ± 0.76	.967	6.93 ± 0.29	7.50 ± 0.51	.370
Average usage (all days) (minutes)	346.8 ± 10.4	320.2 ± 16.5	.195	336.9 ± 6.3	297.9 ± 18.5	.058	317.1 ± 6.9	274.3 ± 17.9	.140	295.7 ± 11.8	309.0 ± 15.4	.202
Average usage (days used) (minutes)	353.1 ± 7.9	343.5 ± 14.8	.317	358.3 ± 5.3	318.2 ± 14.5	.009	347.9 ± 5.6	326.1 ± 12.3	.247	342.3 ± 8.7	336.3 ± 11.0	.647

Data are reported as medians or percentages. AHI = apnea-hypopnea index, APAP = auto-titrating positive airway pressure, BMI = body mass index, LPM = liters per minute, OSA = obstructive sleep apnea, REM = rapid eye movement.

Table 3—The estimated risk factors for high h-average air leakage.

	h-Average Air Leakage (> 40, LPM)		
	Beta (SE)	Crude OR (95% CI)	*P*
Pillow mask (%)	0.672 (0.315)	1.96 (1.05–3.66)	.035
Sex (female, %)	−1.532 (0.533)	0.22 (0.08–0.62)	.005
Age ≥ 65 (%)	0.836 (0.366)	2.31 (1.12–4.76)	.024
Nasal stuffiness (yes, %)	0.142 (0.274)	1.15 (0.67–1.98)	.604
Mouth breathing (yes, %)	0.477 (0.266)	1.61 (0.95–2.73)	.076
Rhinomanometry			
Total resistance less than 75 Pa (before constriction)	−1.833 (1.907)	0.16 (0.00–7.03)	.339
Total resistance less than 150 Pa (before constriction)	−2.436 (1.395)	0.09 (0.01–1.39)	.084
Nasal flow of dominant side less than 75 Pa (before constriction)	0.001 (0.001)	1.00 (1.00–1.00)	.304
Nasal flow of dominant side less than 150 Pa (before constriction)	0.002 (0.001)	1.00 (1.00–1.00)	.013
Nasal flow of dominant side less than 300 Pa (before constriction)	0.002 (0.001)	1.00 (1.00–1.00)	.001
Resistance of dominant side less than 75 Pa (before constriction)	−0.692 (0.517)	0.50 (0.18–1.40)	.184
Resistance of dominant side less than 150 Pa (before constriction)	−0.431 (0.358)	0.65 (0.32–1.32)	.230
Resistance of dominant side less than 300 Pa (before constriction)	−0.091 (0.179)	0.91 (0.64–1.30)	.611
Nasal flow of dominant side less than 75 Pa (after constriction)	0.001 (0.001)	1.00 (1.00–1.00)	.264
Nasal flow of dominant side less than 150 Pa (after constriction)	0.001 (0.001)	1.00 (1.00–1.00)	.041
Nasal flow of dominant side less than 300 Pa (after constriction)	0.000 (0.000)	1.00 (1.00–1.00)	.296
Resistance of dominant side less than 75 Pa (after constriction)	−0.877 (0.895)	0.42 (0.07–2.46)	.330
Resistance of dominant side less than 150 Pa (after constriction)	−0.454 (0.571)	0.63 (0.20–1.97)	.428
Resistance of dominant side less than 300 Pa (after constriction)	−0.546 (0.401)	0.58 (0.26–1.28)	.177
Physical examination			
Tonsil size (1–4)	−0.480 (0.218)	0.62 (0.40–0.95)	.030
Palatal position (1–3)	−0.593 (0.171)	0.55 (0.39–0.77)	.001
Muller maneuver (0–3)	−0.101 (0.169)	0.90 (0.65–1.26)	.551
Body composition			
BMI (kg/m^2)	0.162 (0.034)	1.18 (1.10–1.26)	< .001
Body fat (kg)	0.062 (0.017)	1.06 (1.03–1.10)	< .001
Body fat percentage (%)	0.008 (0.020)	1.01 (0.97–1.05)	.679
Visceral fat area (cm^2)	0.012 (0.004)	1.01 (1.00–1.02)	.001
Abdominal fat percentage (%)	10.590 (2.590)	2.88 (1.73–4.82)	< .001
Neck circumference (cm)	0.217 (0.045)	1.24 (1.14–1.36)	< .001
Waist circumference (cm)	0.016 (0.012)	1.02 (0.99–1.04)	.187
Hip circumference (cm)	0.059 (0.017)	1.06 (1.03–1.10)	.001
Neck-hip ratio (NHR)	13.707 (5.629)	1.15 (1.03–1.28)	.017
Waist-hip ratio (WHR)	−0.787 (1.103)	0.92 (0.74–1.15)	.477
Severity of OSA at diagnosis			

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Table 3—The estimated risk factors for high h-average air leakage. (*Continued*)

	h-Average Air Leakage (> 40, LPM)		
	Beta (SE)	Crude OR (95% CI)	*P*
AHI (events/h)	0.017 (0.006)	1.02 (1.01–1.03)	.004
Obstructive type	0.020 (0.006)	1.02 (1.01–1.03)	.001
Hypopnea type	−0.016 (0.010)	0.98 (0.96–1.00)	.114
REM AHI	−0.020 (0.007)	0.98 (0.97–0.99)	.008
Supine AHI	−0.008 (0.007)	0.99 (0.98–1.01)	.285
Minimal saturation (%)	0.012 (0.006)	1.01 (1.00–1.02)	.044
Periodic limb movements in sleep index	0.004 (0.003)	1.00 (1.00–1.00)	.194
Epworth Sleepiness Scale (0–24)	0.050 (0.024)	1.05 (1.00–1.10)	.045
Berlin questionnaire (0–22)	−0.004 (0.039)	1.00 (0.92 BMI: body mass index, 1.08)	.913

AHI = apnea-hypopnea index, BMI = body mass index, CI = confidence interval, LPM = liters per minute, OR = odds ratio, REM = rapid eye movement.

Table 4—Device-estimated pressure, AHI, and large leakage in HAL and LAL groups.

	LAL (h-Average Air Leakage < 40 LPM)					HAL (h-Average Air Leakage ≥ 40 LPM)				
	Second APAP Follow-up (n = 97)	Third APAP Follow-up (n = 79)	Fourth APAP Follow-up (n = 45)	Beta (SE)	*P*	Second APAP Follow-up (n = 22)	Third APAP Follow-up (n = 21)	Fourth APAP Follow-up (n = 15)	Beta (SE)	*P*
90% Average device pressure	9.1 ± 0.1	9.1 ± 0.2	9.0 ± 0.2	−0.08 (0.12)	.513	10.7 ± 0.4	10.4 ± 0.4	10.4 ± 0.4	−0.12 (0.28)	.664
Mean pressure	7.9 ± 0.1	7.8 ± 0.2	7.7 ± 0.2	−0.08 (0.12)	.497	9.5 ± 0.4	9.1 ± 0.4	9.2 ± 0.4	−0.19 (0.29)	.503
AHI	3.4 ± 0.2	3.4 ± 0.3	3.2 ± 0.2	−0.11 (0.17)	.535	6.7 ± 1.3	5.8 ± 0.9	3.9 ± 0.3	−1.38 (0.74)	.066
Large leakage (%time)	0.4 ± 0.1	0.4 ± 0.1	0.9 ± 0.3	0.26 (0.09)	.002	3.0 ± 0.6	3.3 ± 0.7	3.3 ± 0.7	0.15 (0.50)	.764
Average usage (all days) (minutes)	336.9 ± 6.3	317.1 ± 6.9	295.7 ± 11.8	−0.005 (0.002)	.004	297.9 ± 18.5	274.3 ± 17.9	309.0 ± 15.4	−0.006 (0.002)	.007
Average usage (days used) (minutes)	358.3 ± 5.3	347.9 ± 5.6	342.3 ± 8.7	−0.006 (0.002)	.007	318.2 ± 14.5	326.1 ± 12.3	336.3 ± 11.0	−0.009 (0.003)	.003

AHI = apnea-hypopnea index, APAP = auto-titrating positive airway pressure, HAL = high h-average air leakage group, LAL = low h-average air leakage group, LPM = liters per minute.

In our study, only abdominal fat percentage was more closely associated with air leakage than with BMI, body fat, visceral fat area, hip circumference, and neck/hip ratio. This suggests that regional obesity be more closely related to elevated abdominal pressure and collapsibility of the upper airway and therefore to air leakage than to BMI.

Even after the selection of an appropriate mask type, multiple mask-related problems can be expected, including air leakage, stuffy or dry nose, tube problems, and claustrophobia, among others. Dry or stuffy nose can often be reduced with heated humidification, and claustrophobia can be reduced by desensitization to the mask, change of mask type, and sleep-onset detection.[32]

Contrary to our expectation that higher nasal resistance increases air leakage, rhinomanometry results failed to demonstrate that nasal resistance (obstruction) was related to air leakage, which may be attributable to the lack of a significant difference

Table 5—Association of device-estimated APAP parameters with risk of high h-average air leakage.

	h-Average Air Leakage (LPM)						Crude OR (95% CI)	*P*
	Second APAP Follow-up (1 Month)		Third APAP Follow-up (3 Months)		Fourth APAP Follow-up (6 Months)			
	< 40 (n = 97)	≥ 40 (n = 22)	< 40 (n = 79)	≥ 40 (n = 21)	< 40 (n = 45)	≥ 40 (n = 15)		
90% Average device pressure	9.1 ± 0.1	10.7 ± 0.4	9.1 ± 0.2	10.4 ± 0.4	9.0 ± 0.2	10.4 ± 0.4	1.93 (1.52–2.45)	<.001
Mean pressure	7.9 ± 0.1	9.5 ± 0.4	7.8 ± 0.2	9.1 ± 0.4	7.7 ± 0.2	9.2 ± 0.4	1.89 (1.52–2.35)	< .001
AHI	3.4 ± 0.2	6.7 ± 1.3	3.4 ± 0.3	5.8 ± 0.9	3.2 ± 0.2	3.9 ± 0.3	1.38 (1.17–1.62)	< .001
Large leak (%time)	0.4 ± 0.1	3.0 ± 0.6	0.4 ± 0.1	3.3 ± 0.7	0.9 ± 0.3	3.3 ± 0.7	2.30 (1.66–3.20)	< .001

AHI = apnea-hypopnea index, APAP = auto-titrating positive airway pressure, CI = confidence interval, LPM = liters per minute, OR = odds ratio.

between LAL and HAL groups in total nasal resistance at all follow-ups.

However, previous studies have shown that surgery to decrease nasal resistance is associated with improved PAP compliance, lower PAP pressure, and improved quality of life in patients with OSA.[33–35] A few studies have also reported that nasal airway resistance accounts for up to 60% of total airway resistance, and total nasal resistance does not change significantly between wakefulness and sleep.[36,37] Further study of nasal resistance and air leakage is needed.

The relationship between air leakage and CPAP type may be an issue worth exploring. The type of PAP (fixed or auto) was reportedly not associated with a risk of leaks, but CPAP pressure level (mean) and oronasal masks were associated with a risk of leaks.[16]

Another potential issue involves the effect of air leakage on the function and capacity of PAP devices. Although an automatic analysis from APAP was reported to accurately detect residual sleep apnea, Coller et al reported that, in the presence of air leakage, APAP underestimated the pressure required to treat OSA and overestimated the pressure delivered at the upper airway.[38,39] Baek et al[40] found that higher air leakage was an independent risk factor for greater differences between auto-AHI and manual-AHI scoring. In summary of the abovementioned 2 papers, data estimated by PAP device may not be accurate in the presence of a large air leak. Therefore, effective PAP therapy may also not be possible in the presence of large air leakage.

In our study, the average usage (all days) and average usage (days used) included the time with large air leakage. The proportion of time with large leak was relatively small and may not have affected our results. However, in the presence of large air leak, the device may not properly sense air flow or events or respond or deliver pressures as intended by the auto-algorithms.

Generally speaking, the longer the duration of APAP use, the better patients adapt to APAP; however, our study showed that the longer the duration of APAP use, the higher the h-average air leakage, which may indicate why PAP compliance decreases over time in initially well-adapted APAP users (**Figure 1**).

According to a study by Valentin et al[28], air leakage may be associated with poor adherence to APAP therapy and the proportion of time spent at large leak levels may be associated with nonadherence. Our results showed that a large leak (%time) was a risk factor for air leakage and that it increased even in the LAL group over time (**Table 4** and **Table 5**). These results may be a product of weakened mask-sealing capacity because the silicone portion of the mask tends to stiffen over time, suggesting that the mask should be replaced before 6 months.

Several limitations of this study should be noted. First, each APAP device uses its own algorithm for air leakage, pressure change, and AHI change, which means our results may have been different if we used APAP devices from other manufacturers.[41]

Second, other conditions that affect air leakage, such as upper airway diseases, were not considered.

Third, further research with a larger population should be conducted to assess the effects of other parameters such as mask type and manufacturers on air leakage and the associations between air leakage and PAP treatment effectiveness.

Fourth, each patient's orofacial anatomy and contours can affect mask fit and sealing effects differently; further evaluation of the relationship between orofacial anatomy and mask leakage is therefore needed.

Fifth, the results of age and nasal masks should be interpreted with caution, as our study did not have the necessary power to robustly evaluate those variables.

Finally, the use of single-type cushions could be the limitation of this study, because, if the previously used cushion had some problems such as air leak, it was replaced with extra cushion of same type but different size within 1 month. It might be possible that different type cushions reduced air leakage.

CONCLUSIONS

Our study showed that air leakage increased over time, particularly by 6 months after APAP treatment, which may be due to reduced sealing effects of the masks, suggesting a need for regular mask management. Among the factors related to air leakage, the most consequential appear to be age, sex, mask type, regional obesity, and PAP pressure. Close follow-up and continuous monitoring are recommended for such patients.

ABBREVIATIONS

AHI, apnea-hypopnea index
APAP, auto-titrating positive airway pressure
BMI, body mass index
CI, confidence interval
CPAP, continuous positive airway pressure
HAL, high h-average air leakage
LAL, low h-average air leakage
LPM, liters per minute
OR, odds ratio
OSA, obstructive sleep apnea
PAP, positive airway pressure
PSG, polysomnography
90% ADP, average device pressure under 90% of time

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DISCLOSURE STATEMENT

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